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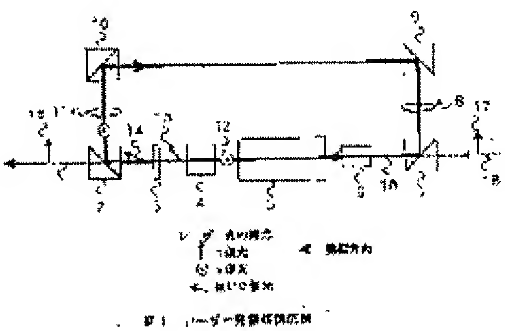
(54) OPTICAL RESONATOR, LASER OSCILLATOR EQUIPPED THEREWITH, AND WAVELENGTH CONVERSION DEVICE



(57)Abstract:

PROBLEM TO BE SOLVED: To provide an optical resonator that can optimize transmissivity (reflection coefficient) of an output mirror of a resonator in various lasers such as wavelength variable laser, solid-state laser, etc., of continuous oscillation and pulse oscillation, without having to change optical elements in the resonator in matching with oscillation forms, such as continuous oscillation, pulse oscillation, etc., in the laser device, and can be applicable as an optical resonator for a wavelength changing device.

SOLUTION: A multilayer coating partially reflection mirror, used as an output mirror of the conventional optical resonator is replaced with a structure

combined with a polarizer and a polarization rotating element, thus enabling change of the transmissivity from zero to 100%.

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[Claim(s)]

[Claim 1] It is the ring type optical resonator characterized by having a polarizer and the optical coupling machine which has arranged polarization rotation components, such as lambda/2 wavelength plate, in front of this polarizer to the incidence sense of laser light polarization. The ring type optical resonator which can make p-polarized light able to rotate laser light polarization continuously from s-polarized light, among those can make only a p-polarized light component penetrate with this polarizer using a polarizer penetrating p-polarized light about 100%, and this optical coupling machine reflecting s-polarized light about 100%.

[Claim 2] The laser oscillation machine which installs a laser head and a Q switch in the optical resonator of claim 1, and is characterized by the oscillation gestalt of both continuous oscillation and a pulse oscillation being possible.

[Claim 3] The optical resonator characterized by replacing all resonator mirrors with a polarizer with the optical resonator of claim 1.

[Claim 4] The laser oscillation machine according to claim 2 characterized by replacing all the resonator mirrors of an optical resonator with a polarizer.

[Claim 5] The laser oscillation machine according to claim 2 or 4 characterized by carrying out incidence of the seed light into a resonator by p-polarized light from a polarizer.

[Claim 6] The wavelength inverter characterized by installing nonlinear crystal in claim 1 or the optical resonator of 3.

[Detailed Description of the Invention]

[0001]

[Field of the Invention] This invention relates to the resonator configuration which can be optimized, without doubling the permeability (reflection factor) of the output mirror of the resonator in various laser, such as tunable laser of continuous oscillation and a pulse oscillation, and solid state laser, with oscillation gestalten, such as continuous oscillation and a pulse oscillation, with the same laser equipment, and exchanging the optical element in a resonator. Moreover, this optical resonator is applicable also as an optical resonator of a wavelength inverter.

[0002]

[Description of the Prior Art] With the conventional laser oscillation vessel, the multilayers coating output mirror of the optimal transmission was used with the gain and optical loss of a laser medium, and oscillation wavelength. Moreover, each equipment needed to be required or it needed to exchange for the output mirror which has the optimal permeability (reflection factor) according to the oscillation gestalt of continuous oscillation and each pulse oscillation.

[0003] Although incidence of the seed light was carried out by p-polarized light from the polarizer in a resonator by injection seeding, it penetrated out of the resonator and seed light was hardly used effectively.

[0004] In the wavelength conversion optical resonator, with the output of an incidence fundamental-wave beam etc., the transmission of a partial transparency mirror was designed and the partial transparency multilayers courting mirror was used.

[0005]

[Problem(s) to be Solved by the Invention] The multilayers courting mirror of the optimal binding fraction (transmission) designed in consideration of gain, optical loss, etc. of a laser medium as an output mirror has been used for the resonator of conventional laser equipment. However, since the optimal binding fraction would also change if gain, loss, and oscillation wavelength change, the output mirror needed to be exchanged for the optimal thing whenever these parameters changed.

[0006] Moreover, to have to use the output mirror of the optimal binding fraction for continuous oscillation and each pulse oscillation and use both oscillation gestalten with one laser equipment, it is necessary to exchange an output mirror according to each oscillation gestalt. Moreover, cost becomes high -- the mirror of the broadband which is needed for tunable laser and an ultrashort pulse laser must coat 100 or more layers of film with multilayers coating.

[0007] Moreover, although incidence of the seed light was carried out by p-polarized light from the polarizer installed in the optical resonator in order to arrange polarization conventionally when incidence was carried out into an optical resonator by making the high laser beam of beam quality into seed light, most of the seed luminous energies were penetrated out of the optical resonator, and the seed luminous energy which enters in an optical resonator was slight, and was not able to use seed light efficiently.

[0008] Although the approach of mold cavity discharge has been used from the former as an approach of taking out energy from a laser oscillator, this changes polarization with an E-OQ switch, with a polarizer, it is made to penetrate or reflect 100%, and it takes out the laser luminous energy accumulated into the resonator, and it is not used in

order to obtain the binding fraction of arbitration.

[0009] When an external resonator was used by wavelength conversion, in the partial transparency multilayers courting mirror used conventionally, transmission could not be changed and the partial transparency mirror which has the optimal transmission was designed according to the output of an incidence fundamental-wave beam. Therefore, when the output of a fundamental-wave beam changed, permeability with the optimal partial transparency mirror also needed to change, and the partial transparency mirror also needed to be exchanged.

[0010]

[Means for Solving the Problem] This invention makes it more possible than transposing to the optical coupling machine of a configuration of having combined the polarizer and the polarization rotation component for the multilayers coating partial reflection mirror used for the output mirror of the conventional optical resonator to change permeability into arbitration to 0 to 100%.

[0011] A polarizer penetrates p-polarized light about 100%, it can use reflecting s-polarized light about 100%, and s-polarized light can be made to rotate laser light polarization continuously from p-polarized light by arranging polarization rotation components, such as lambda/2 wavelength plate, in front of a polarizer to the incidence sense of laser light polarization, among those only a p-polarized light component is outputted from a polarizer. By rotating a polarization rotation component, the transmitted light from a polarizer can be changed freely continuously from 0% to 100%, and it cannot be concerned with change of gain or optical loss, oscillation wavelength, and the oscillation gestalt of a pulse oscillation or continuous oscillation, but a binding fraction with the optimal output mirror can be obtained.

[0012] Furthermore, the seed luminous energy which had almost become futility by the conventional approach about seed light by the ability carrying out incidence of the energy into 100% resonator by a polarizer to p-polarized light can be efficiently used by using the polarizer used in order to arrange polarization as an optical coupling element.

[0013] Moreover, it is also possible to apply this optical resonator as an optical resonator for wavelength conversion, the nonlinear crystal for wavelength conversion is installed in an optical resonator, by controlling a polarization rotation component and cavity length, laser luminous energy can be accumulated into a resonator and high wavelength conversion efficiency can be acquired.

[0014]

[Embodiment of the Invention] The example of a configuration of the laser oscillation machine which used the optical resonator of this invention for drawing 1 is shown.

Since all the mirrors of a resonator are changed to the polarizer, rather than the conventional multilayers mirror, a large oscillation wavelength region can be taken and it can use for the tunable laser of a broadband etc.

[0015] The optical resonator of this invention is a ring type resonator which consisted of polarizers 2, 7, 9, and 10, and although an oscillation wavelength region becomes narrow, it may transpose polarizers 7, 9, and 10 to a mirror. The oscillation direction of a beam progresses in the clockwise direction by the faraday rotator 4, and is amplified by the laser head 5.

[0016] Although an oscillation is oscillated by the s-polarized light 12 level to a polarizer, it becomes the leaning polarization 13 which passed the faraday rotator 4 and was rotated by the FARA day rotator 4, and becomes the leaning polarization 14 which passed lambda/2 wavelength plate 3, and was subsequently rotated with lambda/2 wavelength plate, and only the p-polarized light component 15 of an output laser light still more nearly perpendicular to the polarizer 2 for an output is outputted as an output beam 1.

[0017] By rotating lambda/2 wavelength plate 3, polarization can be rotated continuously and the binding fraction in a polarizer 2 can be changed from 0% to 100%. Lenses 8 and 11 are used in order to adjust the mode of a beam. While the AO-Q switch 6 is not operating, it becomes continuous oscillation, while operating, it becomes a pulse oscillation, and the oscillation of dimorphism voice is possible. And it is each oscillation gestalt and it is possible by rotating lambda/2 wavelength plate 3 to set up the binding fraction in a polarizer 2 the optimal. Moreover, an injection lock can be covered by the p-polarized light 17 penetrated by carrying out incidence of the seed light 16 to a polarizer 7.

[0018] That is, the optical resonator of this invention is characterized by having the optical coupling machine which combined the polarizer 2 and the polarization rotation component of lambda/2 wavelength plate 3. A polarizer penetrates p-polarized light about 100%, and this resonator makes p-polarized light rotate laser light polarization continuously from s-polarized light, and makes only a p-polarized light component output from a polarizer by using reflecting s-polarized light about 100%, and arranging a polarization rotation component in front of a polarizer 2 to the incidence sense of polarization.

[0019] Moreover, the laser oscillation machine of this invention arranges polarizers 2, 7, 9, and 10 to a ring type, and is constituted by installing the AO-Q switch 6 among polarizers 2 and 7 at the faraday rotator 4 and the polarization rotation component of a wavelength plate 3, and laser head 5 list. This oscillator carries out rotatory

polarization of one side of the oscillated s-polarized light 12 with the faraday rotator 4 and a wavelength plate 3, and only the p-polarized light component 14 perpendicular to a polarizer 2 is outputted as an output beam 1.

[0020] The example of a configuration of the wavelength converter which used the optical resonator of this invention for drawing 2 (a) is shown. Since all the mirrors of a resonator are changed to the polarizer and a large oscillation wavelength region can be taken rather than the conventional multilayers mirror, it can use for the tunable laser of a broadband etc. A resonator is a ring type resonator which consisted of polarizers 21, 26, 28, and 30, and although a wavelength region becomes narrow, it can also transpose polarizers 28 and 30 to a mirror.

[0021] Although the fundamental-wave input beam 19 is inputted by p-polarized light 20 to a polarizer 21, it becomes the polarization 22 which combined with the return fundamental-wave beam and inclined. Polarization of a fundamental-wave beam when a fundamental-wave input beam and a return fundamental-wave beam join together is shown in drawing 2 (b). If the polarization 37 of a fundamental-wave input beam and the polarization 38 of a return fundamental-wave beam join together with a polarizer 21, polarization of a beam will turn into the linearly polarized light which piled up in vector and inclined like 39, or elliptically polarized light. becoming the linearly polarized light to which polarization of the united beam inclined -- or in this equipment, although it is dependent on the relative position of the wave of the polarization 37 of a fundamental-wave input beam, and the polarization 38 of a return fundamental-wave beam, whether it becomes elliptically polarized light needs to arrange the phase of a fundamental-wave input beam and a return fundamental-wave beam so that it may become the leaning linearly polarized light. When a phase does not gather but it has become the circular polarization of light and elliptically polarized light, it will have a p-polarized light component to a polarizer 26, a p-polarized light component penetrates, and it is detected by the photodetector 34. Position control of a mirror or the polarizer 28 is carried out with the piezo actuator 36 which tunes the location of the piezo mirror controller 35 or a polarizer finely, respectively so that the detection output of the photodetector in which this transmitted light is shown may become min.

[0022] Subsequently, it rotates by carrying out rotation adjustment of the lambda/2 wavelength plate 23, considers as s-polarized light 24, and reflects by the polarizer or mirrors 8 and 10, and polarization of the united beam is led to nonlinear crystal 29. A fundamental-wave beam connects a focus with nonlinear crystal 29 with a lens 27, and wavelength conversion is carried out. If the crystal of Type I is used for nonlinear crystal 29, the polarization 32 of a beam by which wavelength conversion is carried out

will be p-polarized light, and, subsequently will be outputted from a polarizer 30.

[0023] When using a mirror instead of a polarizer 30, the dichroic mirror which reflects a fundamental-wave beam and lets the beam by which wavelength conversion was carried out pass is used. It is reflected with a polarizer 30, and the fundamental-wave beam by which wavelength conversion was not carried out is returned to a collimated beam with a lens 31, and is again combined with the fundamental-wave incident beam 19 with a polarizer 21.

[0024] The example of this invention is explained below.

[0025]

[Example] The oscillation property when using the laser oscillation machine of drawing 1 for drawing 3 is shown. The Nd:YAG crystal was used for the laser medium and it excited with the semiconductor laser of continuous oscillation. A laser output is shown on the angle of rotation of polarization on an axis of abscissa, and an axis of ordinate.

[0026] In this laser oscillator, polarization of the oscillation laser beam 18 can be continuously rotated by rotating lambda/2 wavelength plate 3, among those only p-polarized light passes a polarizer 2. That permeability changes with the inclination of polarization, to a polarizer 2, if it is completely p-polarized light, it will be penetrated about 100%, but in order not to feed back and amplify in this case, it does not oscillate in practice. On the other hand, although a beam will be shut up in a resonator and beam energy will be accumulated into a resonator if it is completely s-polarized light, beam energy cannot be taken out besides a resonator. Therefore, the optimal permeability which makes a laser output max exists, and the component which adjusts the permeability adjusts the component of p-polarized light by rotating polarization with lambda/2 wavelength plate.

[0027] Although drawing 3 measured change of the output when changing the angle of rotation of this polarization, it was s-polarized light with 0 nearly perfect degree of polarization angles of rotation and it was in the condition that beam energy was shut up in the resonator, in order [being perfect] not to recognize ideal polarizer existence, the beam was somewhat outputted out of the resonator.

[0028] In the continuous oscillation which does not operate an AO-Q switch, when the angle of rotation of polarization was 8 degrees, the output became max, and 2% was obtained as permeability with the optimal wired-AND component at this time.

[0029] On the other hand, when [1% of] an AO-Q switch was operated and a pulse oscillation was performed, the output became max at 6 degrees of polarization angles of rotation, and it was obtained as permeability with the optimal wired-AND component. Although the peak locations in continuous oscillation and a pulse oscillation differ

slightly, this is because the gains of magnification of continuous oscillation and a pulse oscillation differ.

[0030] If the optical resonator of this invention is used, even when using it by different oscillation gestalt in this way, gain, and optical loss, the optimal binding fraction can be obtained.

[0031]

[Effect of the Invention] The following effectiveness occurs by this invention.

(1) It is not based on the gestalt of the gain or optical loss of a laser medium, oscillation wavelength, and laser oscillation, but the optimal optical coupling conditions are acquired with a wired-AND component.

[0032] (2) A pulse oscillation and the oscillation of the dimorphism voice of continuous oscillation are possible with one laser equipment.

(3) The optimal output mirror permeability is obtained with tunable laser in the wavelength variable region of a broadband.

[0033] (4) Injection seeding can be performed effectively.

(5) Since it is an extensive wavelength field, the application to an ultrashort pulse laser is possible.

[0034] (6) The optimal binding fraction is obtained with the optical resonator used for wavelength conversion, and tidal-wave length conversion efficiency is acquired.

[Brief Description of the Drawings]

[Drawing 1] The example of the laser oscillation machine using a binding fraction good light variation resonator is shown.

[Drawing 2] (a) is drawing showing the structure of a wavelength inverter where the binding fraction good light variation resonator was used, and (b) is drawing showing polarization of a fundamental-wave beam when a fundamental-wave input beam and a return fundamental-wave beam join together.

[Drawing 3] It is drawing showing the rate of optical coupling and the relation of a laser output which were carried out using the system shown by drawing 1 . It is considering [the axis of abscissa] as the laser output at the polarization angle of rotation of the beam to a polarizer 2, and the axis of ordinate.

[Description of Notations]

1 Output Beam

2 Polarizer for Output

3 Lambda/2 Wavelength Plate

4 Faraday Rotator

5 Laser Head

6 AO-Q Switch

7 Polarizer

8 Lens

9 Polarizer

10 Polarizer

11 Lens

12 Polarization of Laser Light (S-polarized Light)

13 Polarization of Laser Light Which Rotated by Faraday Rotator 4

14 Polarization of Laser Light Which Rotated with Lambda/2 Wavelength Plate

15 Polarization of Output Laser Light

16 Seed Light

17 Polarization of Seed Light (P-polarized Light)

18 Oscillated Laser Beam

19 Fundamental-Wave Input Beam

20 Fundamental-Wave Input Beam Deflection (P-polarized Light)

21 Polarizer

22 Polarization when Fundamental-Wave Input Beam and Return Fundamental-Wave Beam Join Together

23 Lambda/2 Wavelength Plate

24 Polarization Which Rotated Polarization 22 of Leaning Fundamental-Wave Beam with Lambda/2 Wavelength Plate (S-polarized Light)

25 Fundamental-Wave Beam in Resonator

26 Polarizer

27 Lens

28 Polarizer

29 Nonlinear Crystal

30 Polarizer

31 Lens

32 Output Beam Which Carried Out Wavelength Conversion

33 Polarization of Output Beam by Which Wavelength Conversion was Carried Out

34 Photodetector for Control

35 Piezo Mirror Controller

36 Piezo Actuator

37 Polarization of Fundamental-Wave Input Beam

38 Polarization of Return Fundamental-Wave Beam

39 Polarization of Fundamental-Wave Beam Which Fundamental-Wave Input Beam and Return Fundamental-Wave Beam Combined

[Drawing 1]

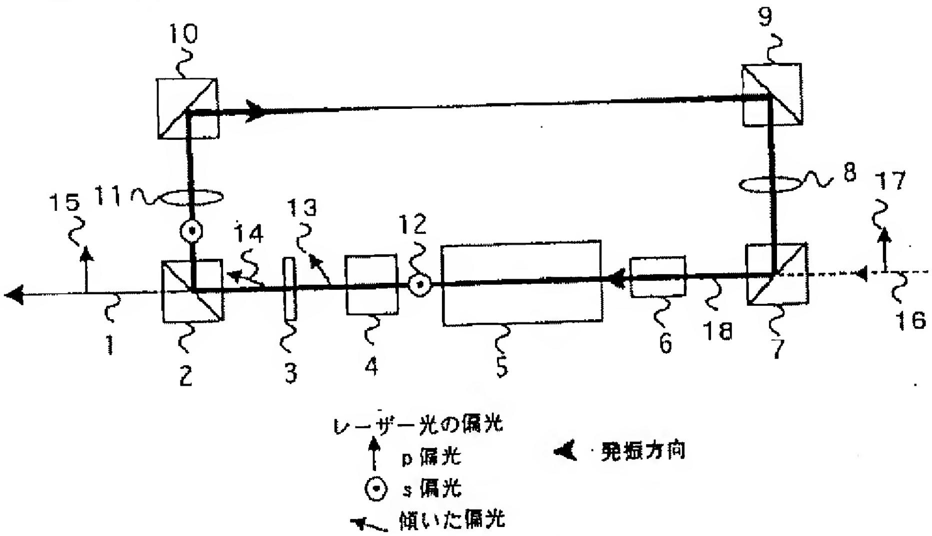

図1　レーザー発振器構成例

[Drawing 3]

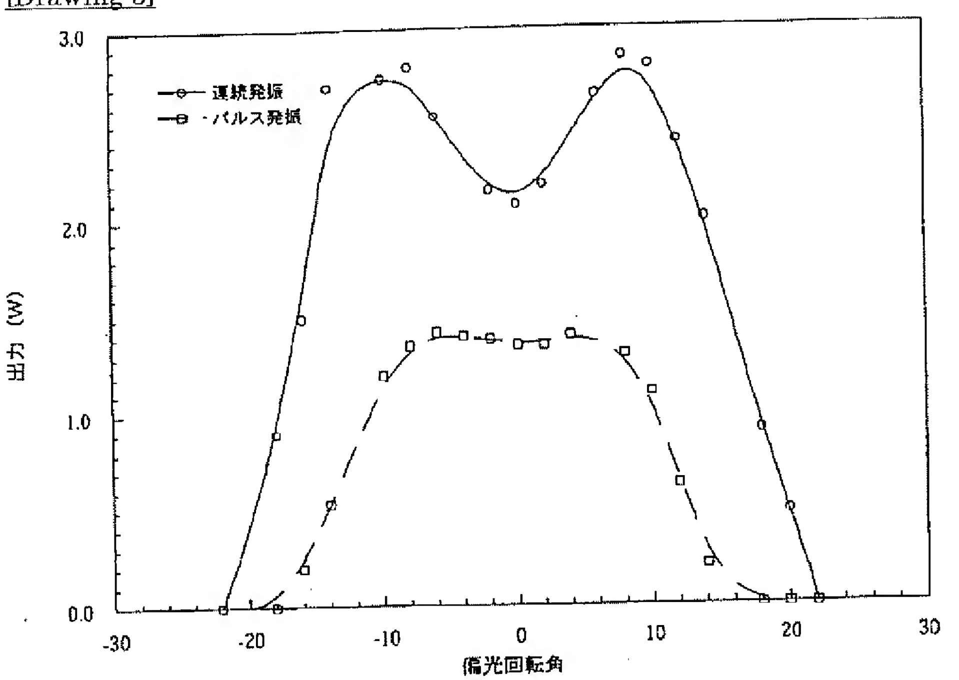

図3　出力結合器におけるビーム偏光と出力

[Drawing 2]

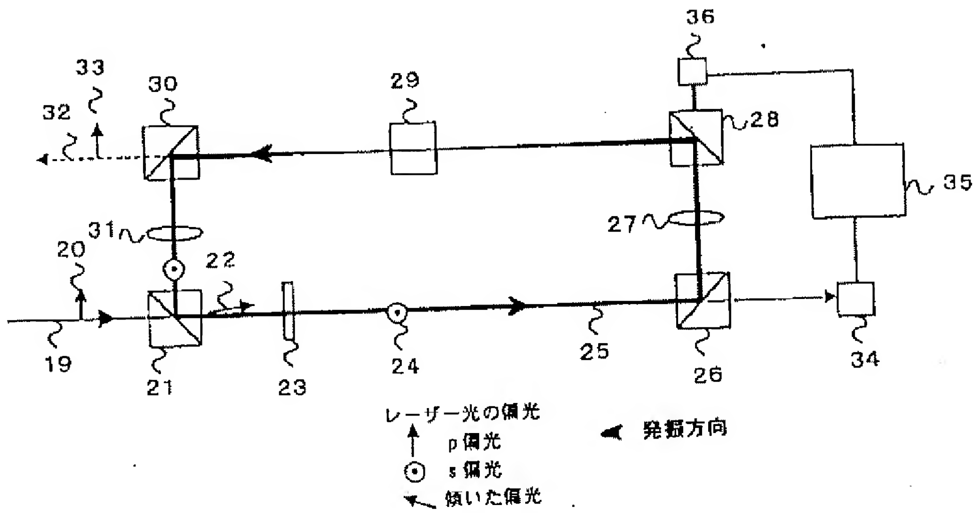

図2(a) 波長変換装置構成例

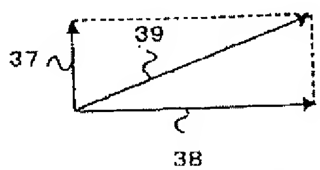

図2(b) 基本波入力ビームと戻り基本波ビームが結合したときの基本波ビームの偏光